Low Temperature Deposition of Ultrananocrystalline Diamond Films

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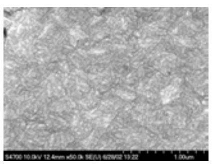
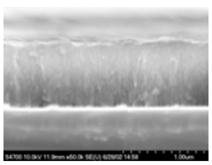
Motivation / Major Accomplishments

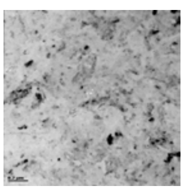
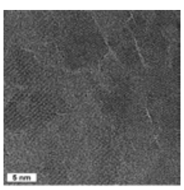
Most diamond CVD processes require substrate temperatures greater than 700°C, which has greatly limited the applications of diamond films for many electronic devices. Therefore, it is critical to decrease the substrate temperature while preserving the microstructure and properties of diamond films. The Ar/CH_4 plasma chemistry enables low temperature growth of ultrnanocrystalline diamond (UNCD) films with relatively high rates, due to low activation energy (~5Kcal/mol) provided by the C_2 growth species, as shown experimentally and theoretically. The optimized seeding process (ultrasonic vibration in the suspension of nano-diamond powders) increased the initial nucleation density (up to 1×10^{11}/cm^2), thus greatly decreasing the time needed for the coalescence of grains to form dense continuous films. LT-UNCD films consisted of 5~10nm, phase pure diamond grains and 0.5nm wide grain boundaries. The currently observed high growth rate (0.2μm/hour) is mainly attributed to the nano-diamond powder seeding process, which enhances the initial nucleation and leads to further enhancement of the secondary nucleation. LT UNCD has been used as the hermetic coating for Retina Swizzle. The *in-vitro* test showed the UNCD is a good candidate for the protective coatings for bio MEMS.

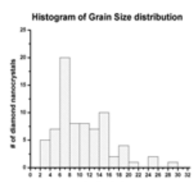
The LT-UNCD is expected to possess excellent mechanical, chemical and tribological properties equivalent to those of the typical high temperature UNCD. The significance of this result is that it allows stress-free films to be deposited at temperatures low enough to be compatible with the Si-based circuit components, and at the same time with deposition rates high enough so that UNCD films can be practically used in current and future MEMS devices, particularly as an anti-stiction coating (stiction is the resistance to the start of motion). Together with the biocompatibility of diamond, the fully dense, continuous and pinhole free LT-UNCD films we have obtained offer great promises for their applications as electrodes and hermetic coatings, especially in the biomedical field.

Results

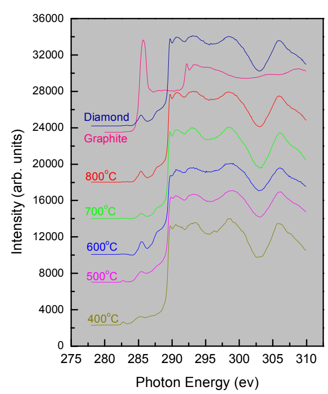



Growth rate
0.25 μm/hr (800°C)
0.20 μm/hr (400°C)

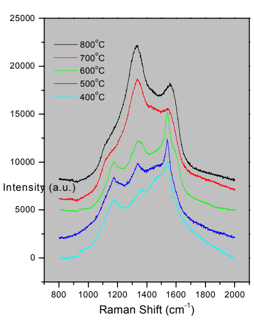





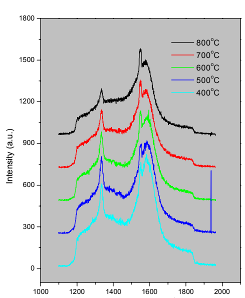
- LT UNCD films have the same nanostructure as that of HT UNCD grown at 800°C. The grain size of LT UNCD films is slightly larger than that of HT UNCD



- NEXAFS provides additional strong evidence for high quality of HT & LT UNCD films
  - A sharp peak at 289.3 eV corresponds to a characteristic diamond core exciton
  - A dip at 302.4 eV is attributed to the second absorption band gap
  - The weak peak of 285 eV indicates the low fraction of sp^2-bonded carbon

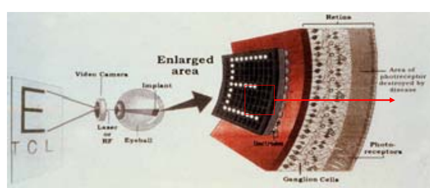


Visible Raman(633nm)

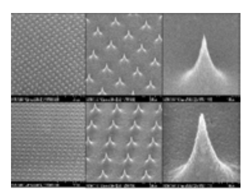


UV Raman(266nm)

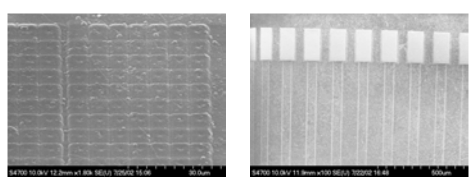
- Visible Raman shows characteristic sp^3 and sp^2 bonding in UNCD films
- UV Raman provides evidence for the microcrystalline diamond inclusion in LT UNCD films revealed by the sharp sp^3 peak in the spectra



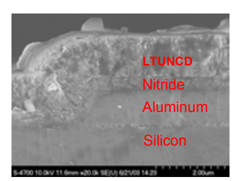
Artificial Retina



Retina Electrode Array



Hermetic Coatings on CMOS



On Retina Swizzle

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